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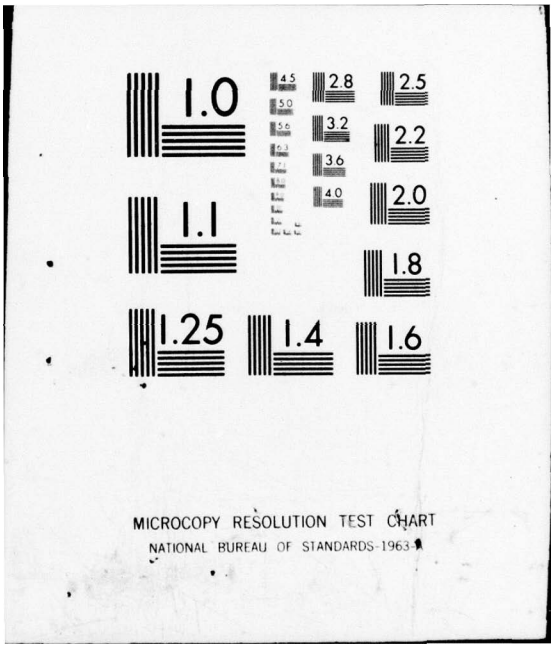
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Report SAM-TR-78-3

LONG-TERM FOLLOWUP OF MACACA MULATTA EXPOSED TO HIGH LEVELS OF 15-, 20-, AND 26-MHz RADIOFREQUENCY RADIATION

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January 1978

Interim Report for Period January-July 1977

USAF SCHOOL OF AEROSPACE MEDICINE
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NOTICES

This interim report was submitted by personnel of the Radiation Physics Branch, Radiation Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7757-01-43.

When U.S. Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

The animals involved in this study were procured, maintained, and used in accordance with the Animal Welfare Act of 1970 and the "Guide *for the Care and Use of Laboratory Animals*" prepared by the Institute of Laboratory Animal Resources-National Research Council.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two groups of rhesus monkeys (Macaca mulatta), totaling 18 animals, were used in a series of experiments in mid-1975 and 1976 to measure the whole-body thermal response to high incident-power levels (500-1270 mW/cm^2) of 15-, 20-, and 26-MHz radiofrequency radiation. Each animal was exposed for up to 6 hours on at least two occasions. One or two years later, standard clinical pathology methods were used to measure a number of hematological and biochemical blood values. Physical examinations were performed, including slit-lamp

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20. Abstract (continued)

examinations of the lens of the eye, and ophthalmoscopic fundus examinations. No variations from normal values or conditions were found that could be attributed to the radiation exposure. For comparison, normal blood values were obtained from data accumulated from 47 nonexposed animals maintained and evaluated locally for a number of years as part of another experiment.

LONG-TERM FOLLOWUP OF *MACACA MULATTA* EXPOSED TO HIGH LEVELS OF 15-, 20-, AND 26-MHz RADIOFREQUENCY RADIATION

INTRODUCTION

Two series of experiments were performed in mid-1975 and 1976 at the USAF School of Aerospace Medicine (USAFSAM), to ascertain the thermoregulatory response of rhesus monkeys (*Macaca mulatta*) to high incident-power levels of 15-, 20-, and 26-MHz radiofrequency radiation (RFR) (4, 7). Following the exposures, the animals were returned to the Veterinary Sciences Division, USAFSAM, for reassignment to other investigators. Increased public interest in the potential for RFR, after an extended period of time, to induce late postexposure effects prompted this investigator to attempt to locate subjects from those experiments. Eighteen animals were identified as still available, ten from the 1975 tests (Group A) and eight from the 1976 experiments (Group B). Blood samples were taken and physical examinations were done to assay their state of health as of early 1977.

MATERIALS AND METHODS

The animals used were 2-year-old male rhesus monkeys, weighing 3.0 $\pm$ 0.5 kg at the time of exposure, obtained from a commercial importer, and quarantined for a minimum of 90 days before use. Prior to and following exposure they were housed in wall-hung individual cages and fed a commercial laboratory chow with isoniazid added, supplemented by apples and lettuce thrice weekly. Water was available ad libitum. Testing for tuberculosis was done quarterly. On the days of exposure, food and water were withheld for 12 hours, and the animals were placed in slotted Lucite exposure cages and transported to the exposure facility in a closed truck. After the exposure runs, the animals were returned to the vivarium and fed. During the interim, from exposure until their use in this study, they were similarly housed and fed in the USAFSAM vivarium.

Radiation

Details of the dosimetry and exposure scheme have been previously reported (4, 7). Briefly, two animals were exposed during each trial, while the remainder were held in cages near the exposure device but outside the radiation field. The exposure chamber was a rectangular coaxial HF-band transmission line. Power was applied from an FRT-6B transmitter operating as a continuous-wave generator at 15, 20, or 26 MHz $\pm$ 0.1 MHz. The electric (E) and magnetic (H) fields were measured with E- and H-field probes calibrated at the National Bureau of Standards.

The cages were placed on the midline of the strip line, parallel to the E field, one behind the other. E-field measurements for the cage nearer the load end were 3% higher. H-field measurements for the exposure volume varied 3%, with the front cage 10% higher than the rear.

Group A animals were exposed for a 6-hour period to 26-MHz RFR at 500, 750, or 1000 mW/cm^2. Some exposures were duplicated as part of the original experimental design. Not all animals received every exposure, but all animals were exposed at least twice. Group B animals all received a 3-hour exposure to 20 MHz at 760 and 1270 mW/cm^2 and to 15 MHz at 775 and 1025 mW/cm^2, for a total of four exposures each. Exposure histories for each group are shown in Table 1.

TABLE 1. LONG-TERM FOLLOWUP, RF-EXPOSED MACACA MULATTA EXPOSURE HISTORY

Group A: 26-MHz 6-hour exposures (July-August 1975)

Animal No.	500 mW/cm^2	750 mW/cm^2	1000 mW/cm^2
1	2	1	1
2	2	1	1
3	1	2	1
4	2	1	1
5	1	--	1
6	1	--	1
7	2	1	1
8	--	2	--
9	--	2	--
10	2	1	1

Group B: 3-hour exposures (May 1976)

	15 MHz		20 MHz	
	775 mW/cm^2	1025 mW/cm^2	760 mW/cm^2	1270 mW/cm^2
All animals	1	1	1	1

Clinical Data

Blood samples were collected by femoral venipuncture after mild anesthesia from 1.0 mg/kg ketamine administration. Types of laboratory determinations used are shown in Table 2.

TABLE 2. ANALYSES USED FOR BLOOD AND SERUM SAMPLES*

Test	Procedure
Leucocyte count	Coulter counter, Model F
Leucocyte differential count	Wright's stained fresh smear
Packed cell volume	Microhematocrit - International microcapillary centrifuge Model M band reader
Hemoglobin concentration	Cyanmethemoglobin - Hycel, Inc.
Total protein	TS meter, American Optical
Albumin, A/G ratio	Cellulose acetate electrophoresis Helena Laboratories, Inc.
Blood urea nitrogen	AutoAnalyzer, Technicon Corp.
Total serum cholesterol	Liebermann-Burchardt reaction
Blood glucose	Total serum-reducing substance Hoffman, J. S., J Biochem 120:51-55 (1937)

*18 young adult Macaca mulatta

Physical Examinations

When blood was collected, each animal was given a physical examination consisting of visual examinations of the skin and oral cavity, chest auscultation, and abdominal palpation. A Zeiss slit lamp and a funduscope were used for direct and indirect observation of the lens and retina after one drop of 10% phenylephrine HCl and two drops of 1% tropicamide ophthalmic solution had been administered to each eye.

RESULTS AND DISCUSSION

No abnormalities were noted during the physical examination. Results of the hematological and biochemical determination are shown in Tables 3 and 4. Normal values for comparison were derived from data collected from normal animals at USAFSAM over a period of several years. Some normal values reported in the literature are shown for comparison. While some values for exposed animals might show statistically significant differences when compared to selected reported values, overall the figures fall within reported normal ranges and none are of practical significance. The slightly higher hemoglobin values are most likely a result of the very long period of stabilization and improved nutrition of

TABLE 3. COMPARATIVE HEMATOLOGICAL VALUES

Source	PCV	Hb	WBC	%Seg	%Lymph	No. of tests	No. of animals
Group A	39.3±2.7[a]	13.6±0.9	7930±1800	33±7.4	65.5±7.5	10	10
Group B	39.6±22	13.5±0.7	8075±1856	34.9±10.4	59.0±11.7	8	8
USAFSAM	43.9±3.2	14.7±1.3	7958±3635	41	58±17.3	29	87
Melville et al. (8)	42.1±2.2	12.2±0.6	10950±2870	41.1±11.4	55.7±11.6	200	200
Rollins et al. (11)	40.1[b]	13.2	10606	34.5	62.2	1200	400
Dillingham et al. (3)	35.7±3.8	12.6±1.4	9960±3600	44.3±19.5	50.4±19.0	274	274

[a]Mean ± standard deviation
[b]Reported as mean and 95% confidence limits

TABLE 4. COMPARATIVE SERUM BIOCHEMICAL VALUES

Source	BUN	Cholesterol	Blood glucose	Total protein	Albumin	A/G ratio	No. of tests	No. of animals
Group A	20.6±4.4[a]	148±29.6	80.1±22.2	6.8±0.6	3.4±0.6	1.0±0.4	10	10
Group B	17.5±2.4	130±28.8	76.3±11.1	6.6±0.5	3.6±0.3	1.2±0.3	8	8
USAFSAM	22.0±6	147±29	84±27	7.1	3.9	1.2±0.2	29	87
Anderson (1)	25.3±3.9	128±34.6	91±14.0	7.8±0.8	4.9±0.5	1.9±0.8	b	
Robinson and Ziegler (10)				7.3±0.4	4.5±0.4	1.8±0.4	333-389	102
Rao and Shipley (9)[c]	23.0±4.4		62.2±11.1				b	
Rollins et al. (11)	19.0[d]			8.04	5.0	1.7	1200	400

[a]Mean ± standard deviation
[b]Number of animals varied for each test
[c]Data for young adults
[d]Reported as mean and 95% confidence limits

the exposed animals. Total protein, albumin, and A/G ratio differences may be affected by a difference in the USAFSAM laboratory method and those reported in the literature.

The deficiencies in this study are apparent: no preexposure values are available; the number of animals is small; and only one sample was available at one point in time. However, some useful information is derived. Even though the exposure would be considered extreme, no gross pathological alterations were seen. The information is also useful in considering a more ambitious long-term project; for example, determining what parameters to observe and providing some estimate of the population variance as a basis for an experimental design.

Most long-term studies reported to date actually represent cumulative exposures, with evaluations made soon after the last exposure, rather than a true long-term followup. Ferri and Hogan (5) reported no effects in rabbits 2 months after exposure to 2.45 GHz RFR, 10 mW/cm^2, for 8-17 weeks, 8 hours/day, 5 days/week. Guy et al. (6) reported no effects to the same RFR for 23-hour exposures daily for 6 months. The time from last exposure to evaluation was not given. Czerski (2) reported on a number of studies, by various investigators, in which exposure to relatively modest power levels produced striking alterations in various hematological systems in several species. The reported exposures extended over weeks to months, but again, the post-exposure period preceding evaluation was brief. No changes of the kind reported were seen in the animals of this study.

In summary, when examined up to 21 months post exposure, no gross alterations from normal due to multiple high-level RFR HF-band exposures were found in these monkeys. The exposures represented levels 15-25 times greater than existing safety limits for man (7).

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